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The Friedman's and Mishkin's hypotheses (re)considered

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Abstract

This paper offers to investigate both the Friedman's and Mishkin's hypotheses on the consequences of inflation on output growth. To this end, we first base these hypotheses in a unified framework. Second, in an empirical work based on OECD countries, we distinguish between short-medium and long run and between headline and core inflation.

We get two main results. First, nominal uncertainty and inflation are positively linked. Second, headline inflation negatively Granger causes output gap (US, Japan, France) but has no effect on potential output growth (US excepted) whereas core inflation impacts potential output growth (UK, Germany) but not output gap (US excepted).

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1 Introduction

Negative effects of inflation on output growth are well known at least in the long run. For Friedman (1980): "Inflation, particularly highly variable inflation, interferes with growth by (a) introducing static into the messages transmitted by the price system, increasing the uncertainty facing individuals and business enterprises, which encourages them to divert attention from productive to protective activities, and (b) inducing governments to adopt such counterproductive false cures as price controls and incomes policy. These adverse effects have sometimes been more than offset by other forces, so that high inflation has not prevented rapid growth" (Friedman and Schwartz, 1980, pp. 55-6). Conversely, the stabilization of inflation rate at a low level is able to improve output growth. This friedmanite hypothesis was carefully scrutinized and related econometric studies undertaken can be classified into the following three surrounding issues. The first one relates to whether high inflation rates might result in more variable inflation and to, subsequently, create more unpredictability in future inflation. However, there appears contradictory evidence of the causal relationship between inflation levels and inflation uncertainty and this leaves macroeconomists uneasy whether the Friedman-Ball (Friedman, 1977 and Ball, 1992) hypothesis really holds (see Davis and Kanago, 2000; Fountas, 2001; Fountas et al., 2002; Grier et al., 2004; Kontonikas, 2004; and Thornton, 2006). The second issue relates to the welfare loss associated with inflation so that unpredictable future inflation tends to distort the efficient allocation of resources through the price mechanism and, hence, to lower total output. Studies that tested the link between the inflation variability and the output growth include Grier and Perry (2000), Hayford (2000), Fountas et al. (2002), Aspergis (2004) and Grier et al. (2004). The results found in these studies are mixed. And finally, the last issue investigates the link between the level and the variability of both inflation and growth (refer to Wilson and Culver, 1999; Grier et al., 2004; Wilson, 2006; and Fountas and Karanasos, 2007), which addresses the simultaneous feedback between the variables of interest. The results derived are also mixed and depend on the samples and econometric methodologies employed.

In the short run, Mishkin (2008) hightlights in a seminal paper that inflation also negatively impacts output growth. Both demand and supply shocks can lead to unstable inflation and a diminution of output growth below its potential level. For example, a negative shock to aggregate demand (a decline of consumer or firm confidence) implies a cut of households or firms spendings. As a result, future inflation and output gap will decrease. Supply shocks can also lead to inflation unstability and a fall of output gap. For New Keynesian models, this negative correlation between inflation and growth is mainly due to misalignment of employment to its efficient level (Blanchard (1997), Ercberg, Henderson and Levin (2000)) and inefficiencies in labor market search (Blanchard and Galí (2006), Galí, Gertler and Lopez-salido (2007)). On its side, the New Neoclassical Synthesis shows that, as some prices move sluggishly, inflation distorts relative prices between goods and services (Goodfriend and King (1997), Rotemberg and Woodford (1997), Woodford (2003)) and thus reduces ouput growth.

Hence, according to both Friedman's and Mishkin's hypotheses, we must expect a significant causality of inflation on output gap and potential output growth. Furthermore, as the increase of inflation must lead to a diminution of output growth, we must observe that nominal variables negatively explain real variables.

In this paper, we offer to evaluate the impacts of inflation on both output gap and potential output growth for main OECD countries. Implicitely based on the Friedman's and Mishkin's hypotheses, the mandate assigned to Central Bank is to achieve price stability at a medium-long run. In this perspective, we may expect that inflation influences both the output gap and the medium-long run output growth.

Moreover, we distinguish between headline inflation and core inflation, measured by CPI less food and energy. The concept of core inflation, developed in the early 1970s by Eckstein (see Eckstein, 1981), can be defined as the inflation rate for which the employment of labor and capital would be stabilized. According to Catte and Slok (2005), core inflation "is connected to the fundamental drivers of the inflation process: excess demand for goods and services, changes in unit labour costs and, ultimately, monetary policy" and is assimilated to "the generalised component of inflation – that is, with the common factor (or a set of common factors) driving all CPI components". These defintions imply that inflation.can be decomposed in two components: core inflation and a transient component. This distinction between these two components of inflation must be associated with the distinction made by Friedman (1963) "between a steady inflation, one that proceeds at a more or less constant rate, and an intermittent inflation, one that proceeds by fits and starts". Most Central Banks base their inflation calculations on consumer price index (Hereafter CPI) rather than on Producer Price Index because CPI well reflects reductions in economic efficiency (Rich and Steindel, 2005): first, CPI variations capture the component of aggregate price movements of goods and services and second, CPI variations imply indexing arrangements that involve somewhat arbitrary reallocations of income across group.

The more familiar core inflation measure as aggregate price growth excluding food and energy was first analyzed by Robert Gordon (Gordon, 1975) and was then adopted by most Central Banks. However, this measure of core inflation is subject to debates among Central Bankers. Reserve Federal shifted from CPI less food and energy in February 2000 toward Personal Consumption Expenditures (PCE) deflator less food and energy as measure of core inflation in order to take into account the quarter modifications of consumption baskets. CPI and PCE indexes are both based on consumer prices but the latter one is calculated as a chained index. Note, however, that these two measures of core inflation both exclude food and energy prices. For Mishkin (2007), member of the Board of the Reserve Federal System, core inflation has many limitations, even if it cannot take into account all possible shocks, is valuable for the conduct of monetary policy as it "provides some greater signal about persistent movements in inflation than does headline inflation itself". On its side, J.C. Trichet (2008), the ECB governor , worries about the exclusion of energy and food prices in the calculation of European core inflation: "ECB research has in particular shown that for the euro area standard measures of core inflation, excluding energy and unprocessed food prices, do not have desirable leading indicator properties" (14 February 2008). This concern is explained by the recent rise in world prices of raw materials and their possible effects on medium-long run price stability inside the Euro area and hence on output growth.

This paper provides several contributions. First, we base both the Friedman's and Mishkin's hypotheses in a theroretical macroeconomic framework. More precisely, we develop a unified model to highlight all possible origins of uncertainty. Second, we implement a Christiano and Fitzgerald filter (hereafter CF filter) to decompose output series in potential output growth, output gap and real uncertainty.

Moreover, as Fountas and Karanasos (2007), we extract inflation variability using a threshold-GARCH or TGARCH model where asymmetric effects of good news and bad news are possible but contrary to them, we use both headline inflation and core inflation to extract uncertainty.

The paper is organized as follows: the theoretical framework relative to the links between monetary disturbances and macroeconomic performance is proposed in section 2 ; section 3 presents the original procedure; section 4 reports our results. Section 5 concludes.

2 Inflation, ouput growth, nominal and real uncertainty: A unified framework

The foregoing analysis of the paper is based on the following theoretical framework:

$$
\begin{aligned}
y_t &\equiv y_t^p + z_t + \varepsilon_t && (1)\\
y_t^p &= \mu + y_{t-1}^p + \zeta_\pi \sigma_\pi^2 && (2)\\
z_t &= -\varphi(L)(i_t - E_{t-1}\pi_t) + \theta(L) z_t + \zeta_\pi \sigma_\pi^2 + g_t && (3)\\
\pi_t &= k_m + \delta(L)\pi_t + \lambda(L) z_t + \varepsilon_t \qquad \varepsilon_t \left| \Omega_{t-1} \rightsquigarrow N\left(0, \sigma_t^2\right) \right. && (4)\\
\alpha &= r^* + \pi^* && (5)\\
i_t^* &= \alpha + \gamma_\pi \left[E_t \pi_{t+k} - \pi^*\right] + \gamma_z \left[E_t z_{t+l}\right] + \gamma_M \left[\Delta m_t^{MTLR} - \Delta m^*\right] && (6)\\
i_t &= \rho i_{t-1} + (1-\rho) i_t^* + \nu_t && (7)\\
m_t - p_t &= k_y y_t - k_i i_t + w_t && (8)
\end{aligned}
$$

where: y_t is the actual value of real GDP; z_t is the output gap; y_t^p is the potential actual value of real GDP; i_t is the nominal interest rate; E_t is the conditional expectation calculated at date t; π_t is the inflation rate; g_t denotes a goods demand-side shock; ε_t denotes a supply-side shock; p_t is the price level; m_t denotes the money supply; w_t denotes a money demand shock (all of the variables, except for the interest rate, are expressed as logarithms); Δm_t^{MTLR} and $\Delta m_t^{d,MTLR}$ denote, respectively, the medium-term/long run (MTLR) components of money supply and money demand growth. Δm^* summarizes the excess of MTLR nominal money growth over MTLR real money demand growth

Eq. (3) is an IS curve, where output gap depends on real interest rate and of its past values. Following the Mishkin's hypothesis (2008), we introduce in this equation inflation uncertainty. $\varphi(L)$ and $\theta(L)$ are lag operators.

Eq. (4) is a « two-pillar » Phillips curve (Gerlach, 2004). It is a standard backward-looking Phillips curve, but with the intercept (k_m) depending on the medium term /long run (MTLR) component of money supply growth relative to the MTLR component of real money demand growth. $\delta(L)$ and $\lambda(L)$ stand for lag operators.

Eq. (6) and Eq. (7) represent the central bank's behaviour. Eq. (6) indicates that the desired value of the nominal interest rate for the current period (i_t^*) is determined by monetary authorities according to an Ireland's rule (Ireland, 2004). Like an inflation target, this rule calls for the Central bank to adjust the short-term nominal interest rate in reaction to deviations of expected inflation and output from their steady-state levels to assure monetary stability in the short-run to medium term. However, this rule also calls for the Central bank to adjust the short-term interest rate to deviations of actual money growth from its medium-term to long run reference value corresponding to the steady state level of nominal money demand. In the case where the interest rate is determined according to the Friedman's k-percent money supply rule.

Eq. (8) is a Friedman-Meltzer type specification of the demand for money (Nelson, 2002) where it depends negatively on the return rate on its substitutes - equities, bonds, physical capital - and positively on the interest rate on monetary assets.

The model encapsulates the proposal we are interested in here. According to Eq. (2) and Eq. (3), inflation uncertainty, due mainly to monetary disturbances, impacts negatively on economic growth as represented by potential output growth and output gap.

3 Empirical analysis

According to the theoretical model, the test of the Friedman's and Mishkin's hypotheses is based on the comparison between inflation rate, inflation variability (nominal uncertainty), output variability (real uncertainty), output gap and potential output growth. In order to get the convenient series, we implement an original method based on the CF filter to get output components and the TGARCH model to extract nominal uncertainty.

3.1 Decompostion of GDP using the CF filter

The decomposition of GDP in a cyclical, a non-cyclical component and an error term in order to test the Friedman's hypothesis can be apprehensive about filters as:

$$y_t \equiv y_t^p + z_t + \varepsilon_t$$

where y_t^p is the potential output growth, z_t the output gap and ε_t the real shock.

More precisely, econometric techniques offer the possibility of extracting cycles that move in given frequency bands (cf. Hodrick and Prescott, 1997; Baxter and King, 1999; and Christiano and Fitzgerald, 2003). Broadly, these methods can be estimated in the frequency domain by minimizing the conditional expected mean-squared error:

$$Min : E\left[(y_t - \widehat{y}_t)^2 \,|z\right], z \equiv (z_1, ..., z_T)$$

$\widehat{y}_t$ is the linear projection of onto every element in the data set, z_t is the component allowed to pass through the filter.

Through these common characteristics, each filter—that are the Hodrick-Prescott filter (1997) (Hereafter the HP filter), the Baxter-King filter (1999) (hereafter the BK filter)) and the CF filter—presents singular features. Contrary to the HP filter, the BK and CF filters can be implemented as well for business cycles (between 1.5 years to 8 years) than for higher frequencies (short run shocks) and lower frequencies (the long run or potential output). Compared to the BK filter, the CF filter uses all observations of a series while the BK filter does not (Cf. Shelley and Wallace, 2005).

In what follows, we implement the CF filter to output data, according to its robustness. We proceed as follows. First, we seasonally adjust ouput series using Census X12 and we isolate the trend cycle component, Ct, that measures variation due to the long-term trend, the business cycle, and other long-term cyclical factors.

Then, using the CF filter, we isolate the business cycle from the potential output. where the considered frequency domain lies between 18 months (1.5 years) to 96 months (8 years). At this stage, output is decomposed as the sum of the cyclical series including the business cycle. Real shocks (considered hereafter as real uncertainty) are obtained by substracting the trend cycle component from the seasonally adjusted output series.

3.2 Extraction of nominal uncertainty

After having decomposed output, we use a TGARCH(p,q) model for extractding nominal uncertainty. The model assumes that the persistence in the dynamics comes from the conditional second moment of the series. Although the GARCH(p,q) conditional variance model is widely used, there are other alternatives to represent the conditional variance of the inflation rate. In the standard GARCH(p,q) model, positive and negative residuals have a symmetric impact on the conditional variance. However it seems relevant to incorporate a threshold element and introduces a Threshold-GARCH (p,q) model, hereafter, TGARCH, that allows for negative residuals to have a different impact on the conditional variance than do positive residuals (Glosten, et. al. 1993):

$$
\begin{aligned}
\pi_t &= \gamma_0 + \gamma_1(L)\,\pi_t + \gamma_2(L)\,z_t + \varepsilon_t \qquad \varepsilon_t \left|\Omega_{t-1} \rightsquigarrow N\left(0, \sigma^2_{\pi,t}\right)\right. \\
\sigma^2_{\pi,t} &= \omega + \alpha(L)\,\varepsilon_t^2 + \delta\left(\varepsilon_{t-1}^2 \times I_{t-1}\right) + \beta(L)\,\sigma^2_{\pi,t} \\
\alpha(L) &= \sum_{i=1}^{p} \alpha_i L^i,\ \beta(L) = \sum_{i=1}^{q} \beta_i L^i,\ \gamma_1(L) = \sum_{i=1}^{r} \gamma_{1i} L^i,\ \gamma_2(L) = \sum_{i=1}^{r} \gamma_{2i} L^i \\
I_{t-1} &= \begin{cases} 1, & \text{if } \varepsilon_{t-1} < 0 \\ 0, & \text{otherwise} \end{cases}
\end{aligned}
$$

where π_t is the inflation rate; z_t is the output gap component on potential output, ε_t error term; Ω_{t-1}, available information set in period t-1; L stands for the lag operator, $\sigma^2_{\pi,t}$, the conditional variance of inflation which depends linearly on past squared-error terms, past variances and on the negative shocks of $\gamma_0, \gamma_1, \gamma_{2,}\omega > 0, \alpha_i, \beta_i \geq 0$ are parameters to be estimated.

$I_{t-1} = 1$ if $\varepsilon_{t-1} < 0$ and 0 otherwise. If the asymmetry parameter δ is negative then negative inflationary shocks result in the reduction of inflation uncertainty.

We include variables in the mean equation by implementing a stepwise process based on a Schwarz criterion. More precisely, the method begins with no added regressors. We select the variable that would lead to the lowest Schwarz value of the TGARCH model were it added to the regression. If the Schwarz value is lower than the Schwarz value of selected regression, the variable is added. The selection goes on by selecting the variable that gives the lowest Schwarz value of the regression, given the inclusion of the first variable. The procedure stops when the Schwarz value of regressions with not yet included variables is greater than the Schwarz value of the selected regression. The maximum number of lags for each variable is 12.

4 Data and results

The empirical work is based on monthly data of Consumer Price Index (headline CPI), Consumer Price Index less food and energy (core CPI) and the Industrial Price Index (IPI) obtained from the OECD database for US, Japan, UK, Canada, France and Germany. These series are respectively used as proxies of general price level and output. Our analysis covers the period 1957M2-2007M12.

We proceed in several steps.

First, using the methodology presented in section 3, we decompose IPI series in a cyclical, a non-cyclical component and an error term (See figures in annex).

Second, we test for unit roots. ADF tests (with 4 lags) indicate that we can reject the null hypothesis for all considered series at 1% level (Table 1).

[Table 1 here]

Third, we extract the variability of (headline) inflation (i.e. nominal uncertainty) using TGARCH models (Table 2). The relevant variables are determined by a stepwise analysis based on a Schwarz criterion where the maximum number of lags for inflation and real output growth is equal to 12.

Results show that headline inflation and real output growth are significantly and positively linked in US, UK and Germany. For the other countries, our results highlight that real output growth is not a significant determinant of inflation. The conditional variance equation of inflation rate (inflation uncertainty) shows that asymetries are significant for US, Japan, UK and Germany but not for Canada and France. Moreover, each variance is defined and stable as the sum of coefficients is positive and inferior to 1.

[Table 2 here]

In order to implement Granger causality tests of the Friedman's hypothesis, we build a VAR model between inflation, nominal uncertainty, real uncertainty (as defined in section 3) and output gap or potential output growth. The optimal number of lags is determined by a Schwarz criterion.

With regards to the short run where output gap is included to the VAR system (table 3), Granger causality tests offer three main results. First, they indicate a causality between inflation and uncertainty of inflation US, Japan, UK, Canada and France but not in Germany. According to the VAR coefficients this link is positive, which coincides to a part of the Mishkin's hypothesis: the higher the inflation, the higher the nominal uncertainty. Second, our results bring to the fore that output gap positively Granger causes inflation in all considered OECD countries, France excepted. Third, evidence is mixed regarding the link between nominal uncertainty and output gap: even if the sign is negative in all cases, as suggested by the Mishkin's hypothesis, Granger causality is only significant for US, Japan and France[1].

[Table 3 here]

The test of the Friedman's hypothesis offers mixed results (table 4). As in the short run, inflation positively Granger causes nominal uncertainty, Germany excepted. However, the link between nominal and real variables is not significant in most countries: inflation negatively Granger causes potential output growth only for the US.

Table 4 also highlights that potential output growth negatively Granger causes real uncertainty in all considered countries.

[Table 4 here]

This last result may be explained by the fact that headline inflation is not the best measure of long run inflation and thus cannot have any impact on potential

[1] As the series of nominal uncertainty is built from estimated coefficients, we test the robustness of these results with bootstrap techniques. Results are quite robust (and available on request).

output growth (Mishkin, 2007). Hence, we proceed to a similar analysis (i.e., VAR and Granger analysis) with core inflation, based on the CPI less food and energy (tables 5 and 6).

In the short run, our results show that core inflation gives quite similar results as those obtained with headline inflation (table 5). Core inflation positively Granger causes nominal uncertainty in all countries, Canada and Germany excepted. Results are less clear about the link between core inflation and output gap: if output gap positively Granger causes core inflation US, Japan and Germany, core inflation has no impact on output gap for any country. This result may be explained by the fact that core inflation only modifies output growth in the medium-long run.

[Table 5 here]

In the long run, however, the link between nominal variables and potential output growth is significant only for UK and Germany (table 6). For UK, results are quite surprising as core inflation positively Granger causes potential output growth. Note however that nominal uncertainty negatively Granger causes potential output growth. Hence, core inflation, measured as CPI less food and energy prices movements does not appear to be a better indicator of long run price movements, Germany and UK excepted.

[Table 6 here]

5 Concluding remarks

This paper provides several findings. First, the Friedman's and Mishkin's hypotheses are formulated within an unified theoretical framework. Second, we suggest to decompose output growth in potential output growth, output gap and a residual in order to disinguish between the short run Mishkin's statement and the medium-long run Friedman's hypothesis. Third, we implement TGARCH methods in order to extract nominal uncertainty. Then, we both test the Mishkin and Friedman's proposals with Granger causality tests on headline and core inflation, nominal uncertainty, real uncertainty, output gap and potential output growth.

Our results show that both headline and core inflation are positively linked with nominal uncertainty. Headline inflation negatively Granger causes output gap in US, Japan, UK Canada and Germany but has no impact on potential output growth, US excepted. Compared to headline inflation, core inflation, measured as CPI less food and energy prices movements, is better for taking into account fundamental drivers of the inflation process only in UK and Germany. This result may be explained by the fact that our measure of core inflation is a basic measure that is not necessarily the most accurate: a prolongation to this paper would be to implement our method by considering finer measures of core inflation.

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Table 1
ADF unit root tests

Variables	US	Japan	UK	Canada	France	Germany
Real uncertainty	-12.65***	-12.17***	-12.79***	-12.15***	-16.23***	-11.93***
Output gap	-4.14***	-4.56***	-4.25***	-4.48***	-4.55***	-5.00***
Potential output growth	-6.95***	-3.53***	-7.32***	-6.19***	-7.14***	-5.69***
Inflation	-5.58***	-6.83***	-6.01***	-5.48***	-4.21***	-9.14***
Core inflation	-4.49***	-5.17***	-5.57***	-4.72***	-4.12***	-8.43***
Nominal uncertainty	-5.73***	-3.23**	-2.88**	-7.66***	-8.81***	-8.39***

Note: *, **, * respectively indicates rejection of the null at 1%, 5% and 10% significance levels. ADF unit root tests are implemented with 4 lags.**

Table 2
T-GARCH(1,1) models

	US	**Japan**	**UK**	**Canada**	**France**	**Germany**
Mean equation (dependent variable : Headline inflation)						
Inflation						
t-1	0.28***		0.09***		0.29***	0.16***
t-2				0.12**		
t-3				0.13***	0.18***	
t-4				0.17***		
t-6		0.12***	0.15***		0.21**	
t-7	0.16***					
t-9				0.12**		
t-10						0.13**
t-11	0.15***					
t-12	0.22***	0.55***	0.66***	0.27***	0.25***	0.5***
Output growth						
t-2	0.05***					
t-5			0.04*			
t-7			0.04***			
t-12						0.02***
$\widehat{\gamma}_0$	3.79E-04***	4.68E-04***	3.42E-04***	7.02E-04***	2.46E-04***	4.66E-04***
Variance Equation ($\hat{\sigma}^2_{\pi,t}$)						
$\widehat{\omega}$	7.46E-07***	5.18E-07*	2.06E-07	8.79E-07*	2.76E-06**	1.30E-06**
$\hat{\varepsilon}^2_{t-1}$	0.28***	0.09***	0.14***	0.07**	0.16	0.06*
$\hat{\varepsilon}^2_{t-1} \times I_{t-1}$	-0.2**	-0.13***	-0.17***	-0.06	-0.1	0.18*
$\hat{\sigma}^2_{t-1}$	0.71***	0.94***	0.93***	0.89***	0.4*	0.69***

Note: *, **, * respectively indicates rejection of the null at 1%, 5% and 10% significance levels.**

Table 3
Granger-causality tests between headline inflation, nominal uncertainty, real uncertainty and output gap

US	Headline inflation	Nominal uncertainty	Output gap	Real uncertainty
Headline inflation		115.13***(+)	1.89(+)	13.6**(-)
Nominal uncertainty	8.91(+)		12.79***(-)	2.71(-)
Output gap	18.09***(+)	6.12(+)		8.43(+)
Real uncertainty	4.88(+)	3.98(+)	2.86(+)	
Japan	Headline inflation	Nominal uncertainty	Output gap	Real uncertainty
Headline inflation		393.82***(+)	4.75(+)	7.97*(+)
Nominal uncertainty	80.9***(+)		12.05***(-)	4.28(-)
Output gap	35.64***(+)	10.25**(+)		4.37(+)
Real uncertainty	1.87(-)	7.82*(+)	2.87(-)	
UK	Headline inflation	Nominal uncertainty	Output gap	Real uncertainty
Headline inflation		344.08***(+)	1.14(+)	7.29(+)
Nominal uncertainty	32.3***(+)		6.79(-)	2.42(-)
Output gap	15.35***(+)	7.48(+)		8.19(+)
Real uncertainty	7.1(+)	7.07(-)	11.2**(+)	
Canada	Headline inflation	Nominal uncertainty	Output gap	Real uncertainty
Headline inflation		218.64***(+)	1.1(+)	3.09(-)
Nominal uncertainty	15.29***(-)		5.75(-)	2.11(-)
Output gap	9.18*(+)	4.44(+)		6.28(-)
Real uncertainty	1.07(+)	3.28(-)	4.72(+)	
France	Headline inflation	Nominal uncertainty	Output gap	Real uncertainty
Headline inflation		117.34***(+)	1.28(-)	3.91(-)
Nominal uncertainty	6.88(-)		15.84***(-)	3.39(+)
Output gap	5.31(+)	7.08(+)		7.31(+)
Real uncertainty	8.87(+)	1.54(-)	20.65***(+)	
Germany	Headline inflation	Nominal uncertainty	Output gap	Real uncertainty
Headline inflation		4.55(+)	2.23(+)	4.05(+)
Nominal uncertainty	17.67***(+)		0.29(-)	2.51(-)
Output gap	8.08*(+)	9.12*(+)		2.3(-)
Real uncertainty	4.09(-)	3.88(+)	6.69(+)	

Notes: A (+) (resp. (-)) indicates that the sum of the lagged coefficients of the causing variable is positive when (+) or negative when (-). *, **, * respectively indicates rejection of the null at 1%, 5% and 10% significance levels. Numbers are the Chi-squared.**

Table 4
Granger-causality tests between headline inflation, nominal uncertainty, real uncertainty and potential output growth

US	Headline inflation	Nominal uncertainty	Potential output	Real uncertainty
Headline inflation		127.66***(+)	11.54**(-)	3.56(-)
Nominal uncertainty	15.24***(+)		7.16(-)	1.74(-)
Potential output	12.05**(+)	0.66(+)		95.13***(-)
Real uncertainty	0.68(-)	1.43(+)	4.95(+)	
Japan	Headline inflation	Nominal uncertainty	Potential output	Real uncertainty
Headline inflation		415.6***(+)	1.59(-)	5.08(+)
Nominal uncertainty	54.01***(+)		1.84(+)	3.37(-)
Potential output	6.37*(+)	1.83(-)		19.59***(-)
Real uncertainty	1.26(-)	5.4(+)	3.26(+)	
UK	Headline inflation	Nominal uncertainty	Potential output	Real uncertainty
Headline inflation		326.98***(+)	1.45(+)	4.58(+)
Nominal uncertainty	18.81***(+)		3.35(-)	1.83(-)
Potential output	6.44*(-)	4.92(+)		91***(-)
Real uncertainty	9.52***(+)	1.47(+)	3.45(-)	
Canada	Headline inflation	Nominal uncertainty	Potential output	Real uncertainty
Headline inflation		204.27***(+)	16.32(-)	2.25(-)
Nominal uncertainty	16.1***(+)		5.03(+)	1.99(-)
Potential output	2.62*(-)	0.43(-)		26.45***(-)
Real uncertainty	0.63***(+)	2.83(-)	5.53(-)	
France	Headline inflation	Nominal uncertainty	Potential output	Real uncertainty
Headline inflation		123.67***(+)	2.45(-)	1.75(-)
Nominal uncertainty	1.17(-)		1.09(-)	3.15(+)
Potential output	1.87(+)	4.79(+)		86.58***(-)
Real uncertainty	2.33(+)	1.98(+)	5.1(+)	
Germany	Headline inflation	Nominal uncertainty	Potential output	Real uncertainty
Headline inflation		3.98(+)	4.78(-)	1.38(+)
Nominal uncertainty	14.99***(+)		0.87(-)	3.54(-)
Potential output	4.39(-)	6.02(-)		48.92***(-)
Real uncertainty	1.6(-)	5.49(+)	0.79(-)	

Table 5
Granger-causality tests between core inflation, nominal uncertainty, real uncertainty and output gap

US	Core inflation	Nominal uncertainty	Output gap	Real uncertainty
Core inflation		27.38***(+)	2.78(+)	12.19*(-)
Nominal uncertainty	30.23***(+)		13.97**(-)	28.81***(-)
Output gap	19.19***(+)	11.76*(+)		10.13(-)
Real uncertainty	6.05(+)	2.6(+)	4.64(+)	
Japan	Core inflation	Nominal uncertainty	Output gap	Real uncertainty
Core inflation		154.62***(+)	0.46(+)	2.28(+)
Nominal uncertainty	64.64***(+)		4.21(-)	1.16(+)
Output gap	28.88***(+)	21.52***(+)		1.9(+)
Real uncertainty	2.24(+)	3.4(-)	1.89(-)	
UK	Core inflation	Nominal uncertainty	Output gap	Real uncertainty
Core inflation		214.51***(+)	6.45(-)	9.27(+)
Nominal uncertainty	15.77**(+)		10.35(-)	3.44(-)
Output gap	9.98(+)	7.82(+)		10.13(+)
Real uncertainty	15.28**(+)	9.63(-)	17.91***(+)	
Canada	Core inflation	Nominal uncertainty	Output gap	Real uncertainty
Core inflation		33.65***(-)	3.03(-)	3.58(-)
Nominal uncertainty	6.86(+)		3.57(-)	6.15(-)
Output gap	3.98(+)	3.49(+)		5.94(-)
Real uncertainty	1.06(+)	1.24(-)	4.57(+)	
France	Core inflation	Nominal uncertainty	Output gap	Real uncertainty
Core inflation		113.02***(+)	3.44(-)	6.93(-)
Nominal uncertainty	11.94**(+)		9.62*(-)	8.36(-)
Output gap	3.43(+)	8.2(+)		6.77(+)
Real uncertainty	13.76**(+)	2.62(-)	22.1***(-)	
Germany	Core inflation	Nominal uncertainty	Output gap	Real uncertainty
Core inflation		3.44(-)	2.93(-)	4.97(+)
Nominal uncertainty	7.54(+)		1.05(-)	0.87(-)
Output gap	10.03*(+)	2.61(+)		2.07(-)
Real uncertainty	2.49(-)	3.67(+)	7.49(+)	

Notes: A (+) (resp. (-)) indicates that the sum of the lagged coefficients of the causing variable is positive when (+) or negative when (-). *, **, * respectively indicates rejection of the null at 1%, 5% and 10% significance levels.**

Table 6

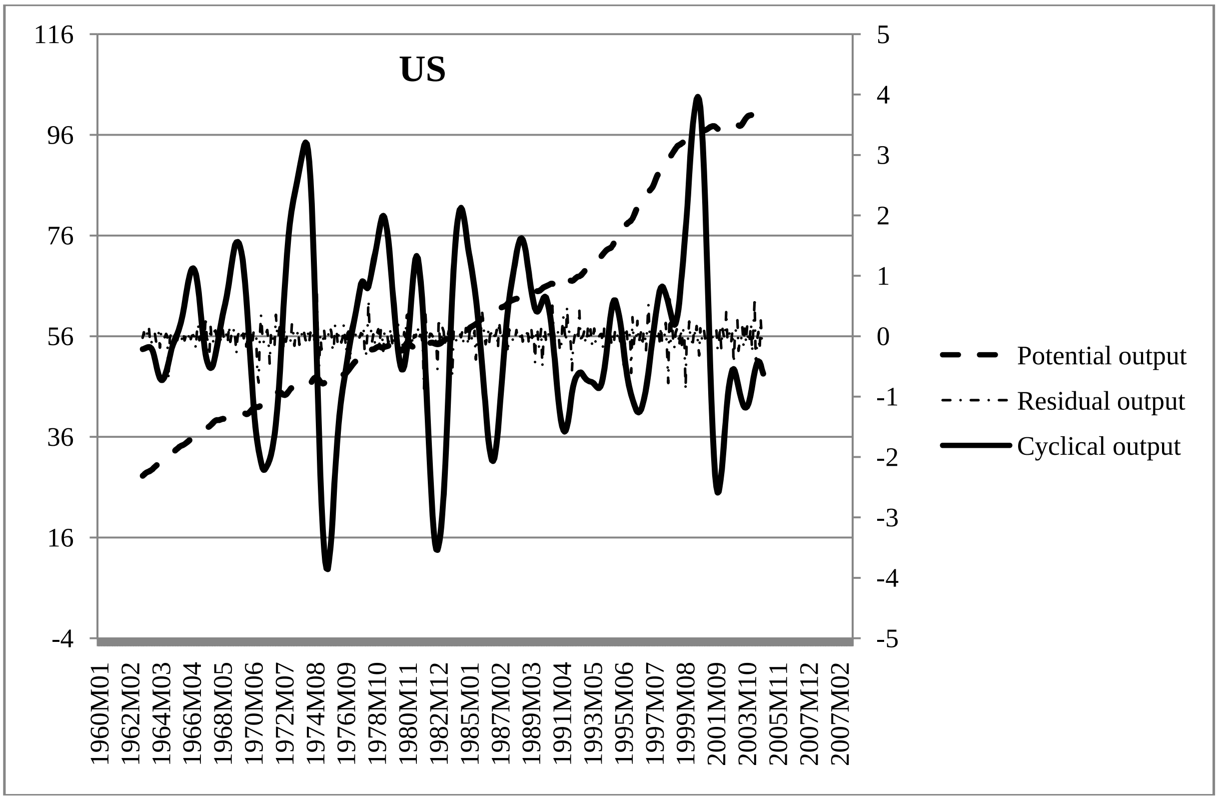
Granger-causality tests between core inflation, nominal uncertainty, real uncertainty and potential output growth

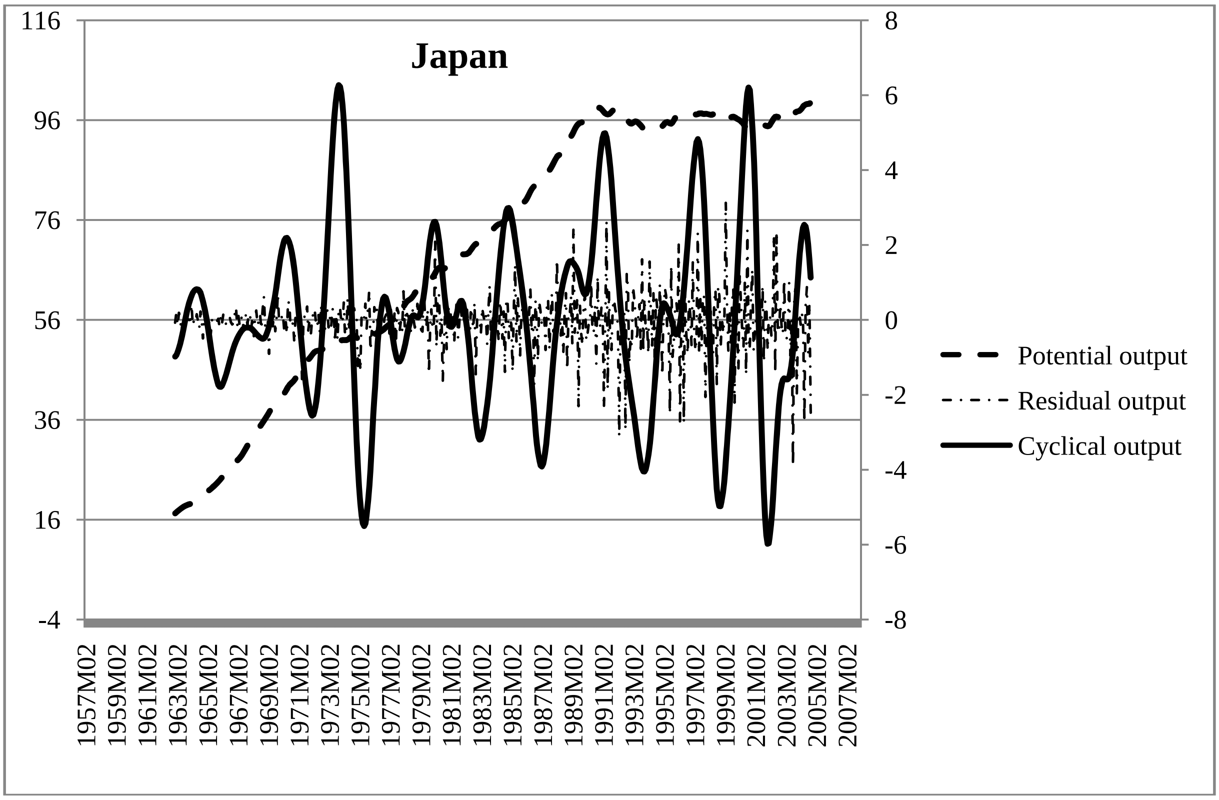
US	Core inflation	Nominal uncertainty	Potential output	Real uncertainty
Core inflation		40.26***(+)	8.49(-)	7.2(-)
Nominal uncertainty	23.89***(-)		3.55(-)	33.28***(+)
Potential output growth	20.86***(+)	10.34(+)		157.29***(+)
Real uncertainty	8.85(-)	3.45(-)	22.28***(+)	
Japan	Core inflation	Nominal uncertainty	Potential output	Real uncertainty
Core inflation		162.9***(+)	1.22(+)	1.45(+)
Nominal uncertainty	51.16***(+)		0.59(-)	1.41(+)
Potential output growth	9.22**(+)	8.17**(-)		15.7***(-)
Real uncertainty	1.11(-)	1.88(-)	4.09(+)	
UK	Core inflation	Nominal uncertainty	Potential output	Real uncertainty
Core inflation		179.64***(+)	9.28**(+)	4.17(+)
Nominal uncertainty	18.24***(+)		16.01***(-)	1.07(+)
Potential output growth	5.34(+)	6.46*(-)		78.35***(-)
Real uncertainty	14.36***(-)	0.12(-)	4(+)	
Canada	Core inflation	Nominal uncertainty	Potential output	Real uncertainty
Core inflation		25.89***(-)	5.53(-)	3.57(-)
Nominal uncertainty	4.59(+)		1.79(+)	3.43(-)
Potential output growth	4.91(-)	1.27(-)		26.55***(-)
Real uncertainty	0.77(+)	1.2(-)	6.4*(-)	
France	Core inflation	Nominal uncertainty	Potential output	Real uncertainty
Core inflation		101.99***(+)	2.26(-)	2.34(-)
Nominal uncertainty	12.58***(+)		5.3(-)	2.3(-)
Potential output growth	4.79(+)	7.18*(+)		89.13***(-)
Real uncertainty	1.94(+)	2.02(+)	5.02(+)	
Germany	Core inflation	Nominal uncertainty	Potential output growth	Real uncertainty
Core inflation		2.88(+)	7.55*(-)	2.23(+)
Nominal uncertainty	6.34*(+)		0.88(-)	1.5(-)
Potential output growth	4.29(-)	10.02**(-)		48.47***(-)
Real uncertainty	0.55(-)	3.6(+)	0.73(-)	

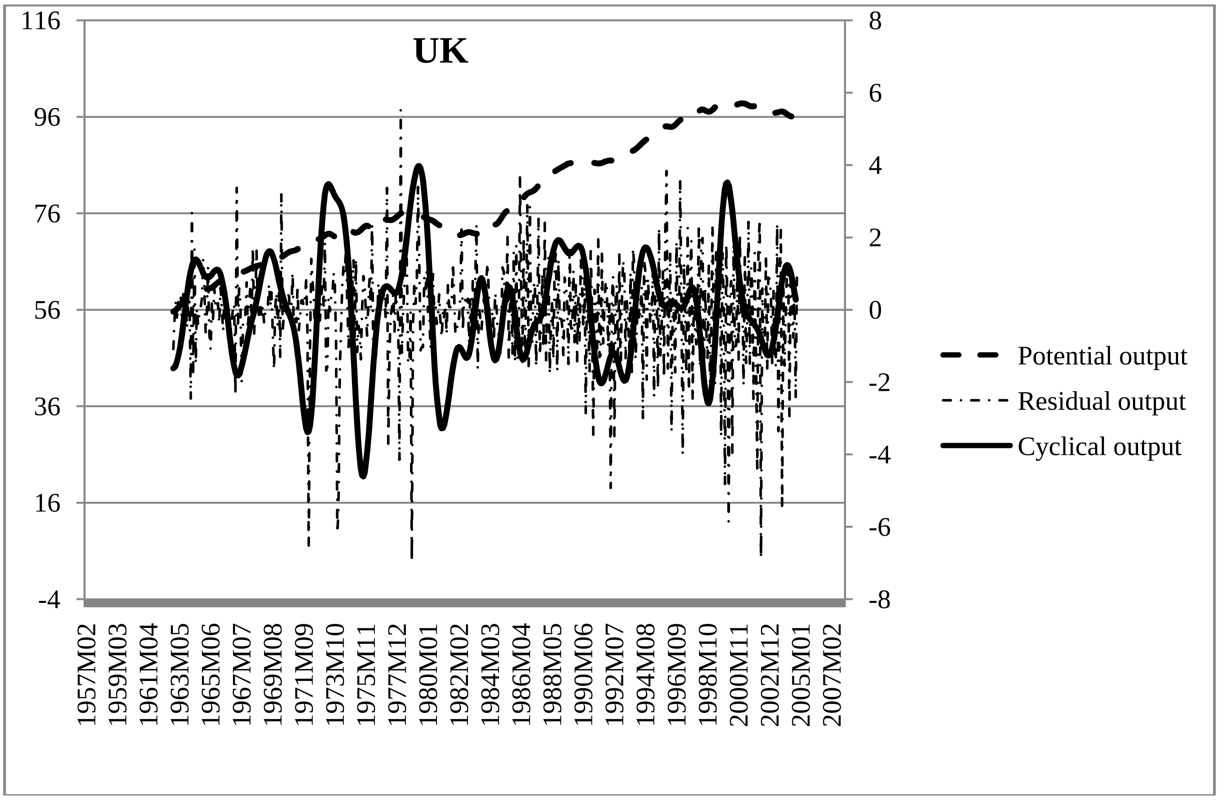
Notes: A (+) (resp. (-)) indicates that the sum of the lagged coefficients of the causing variable is positive when (+) or negative when (-). *, **, * respectively indicates rejection of the null at 1%, 5% and 10% significance levels.**

Figure(s)

Annex: Decomposition of potential output, cyclical output and residual output using the Christiano and Fitzgerald's filter






UK
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96
76
56
36
16
-4
8
6
4
2
0
-2
-4
-6
-8
Potential output
Residual output
Cyclical output
1957M02
1959M03
1961M04
1963M05
1965M06
1967M07
1969M08
1971M09
1973M10
1975M11
1977M12
1980M01
1982M02
1984M03
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1992M07
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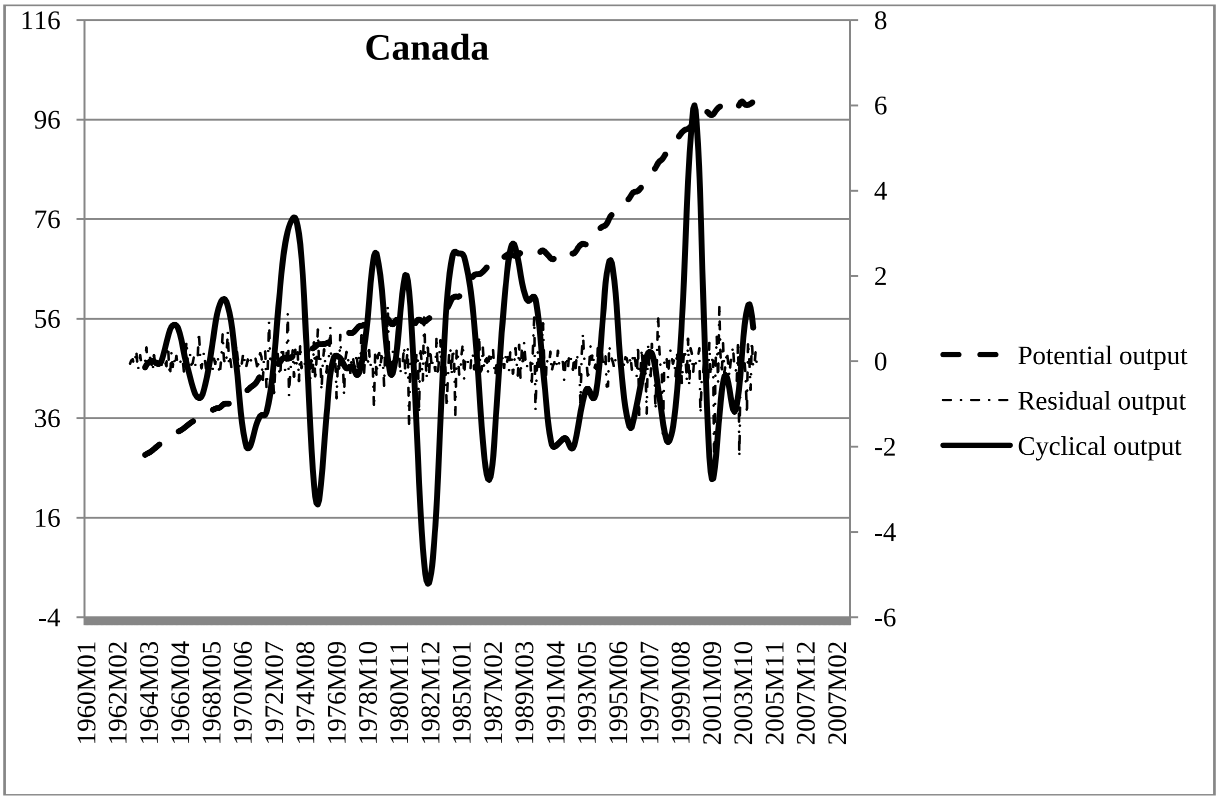
1996M09
1998M10
2000M11
2002M12
2005M01
2007M02


Canada
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96
76
56
36
16
-4
8
6
4
2
0
-2
-4
-6
Potential output
Residual output
Cyclical output
1960M01
1962M02
1964M03
1966M04
1968M05
1970M06
1972M07
1974M08
1976M09
1978M10
1980M11
1982M12
1985M01
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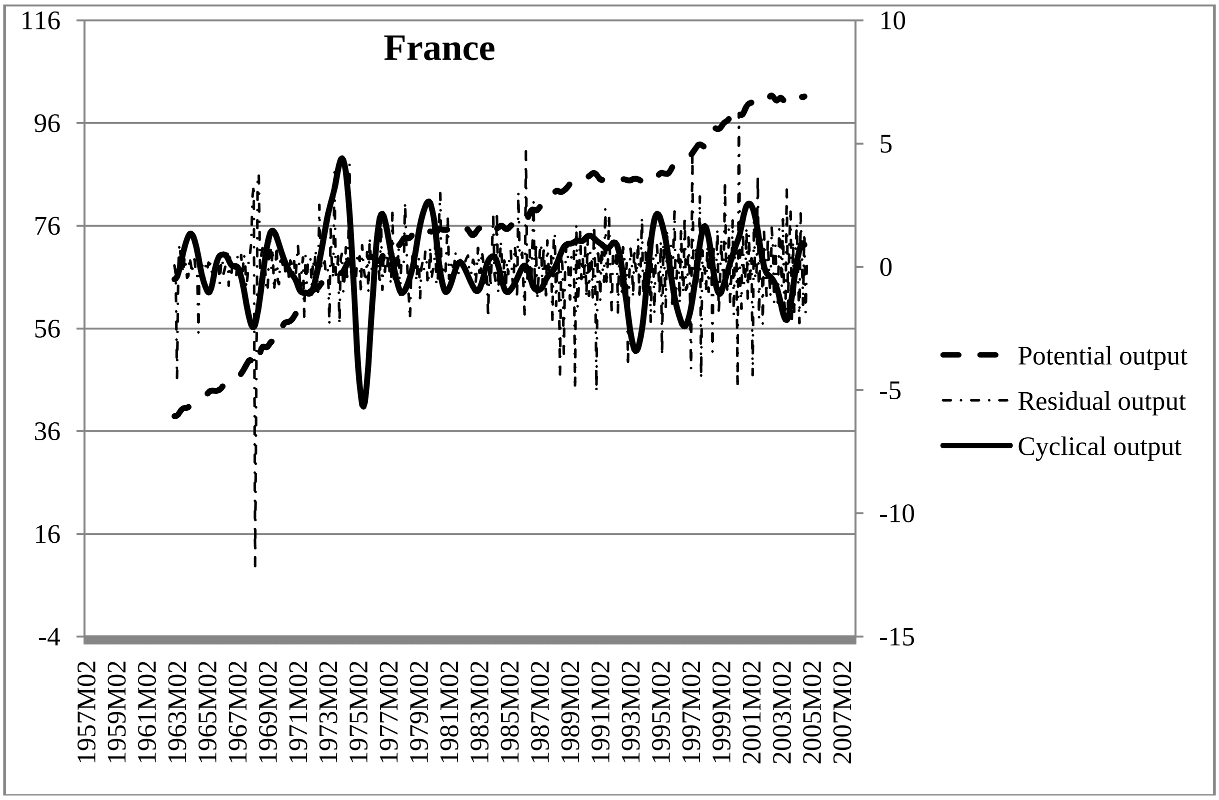
2005M11
2007M12
2007M02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96
76
56
36
16
-4
10
5
0
-5
-10
-15
Potential output
Residual output
Cyclical output
1957M02
1959M02
1961M02
1963M02
1965M02
1967M02
1969M02
1971M02
1973M02
1975M02
1977M02
1979M02
1981M02
1983M02
1985M02
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1995M02
1997M02
1999M02
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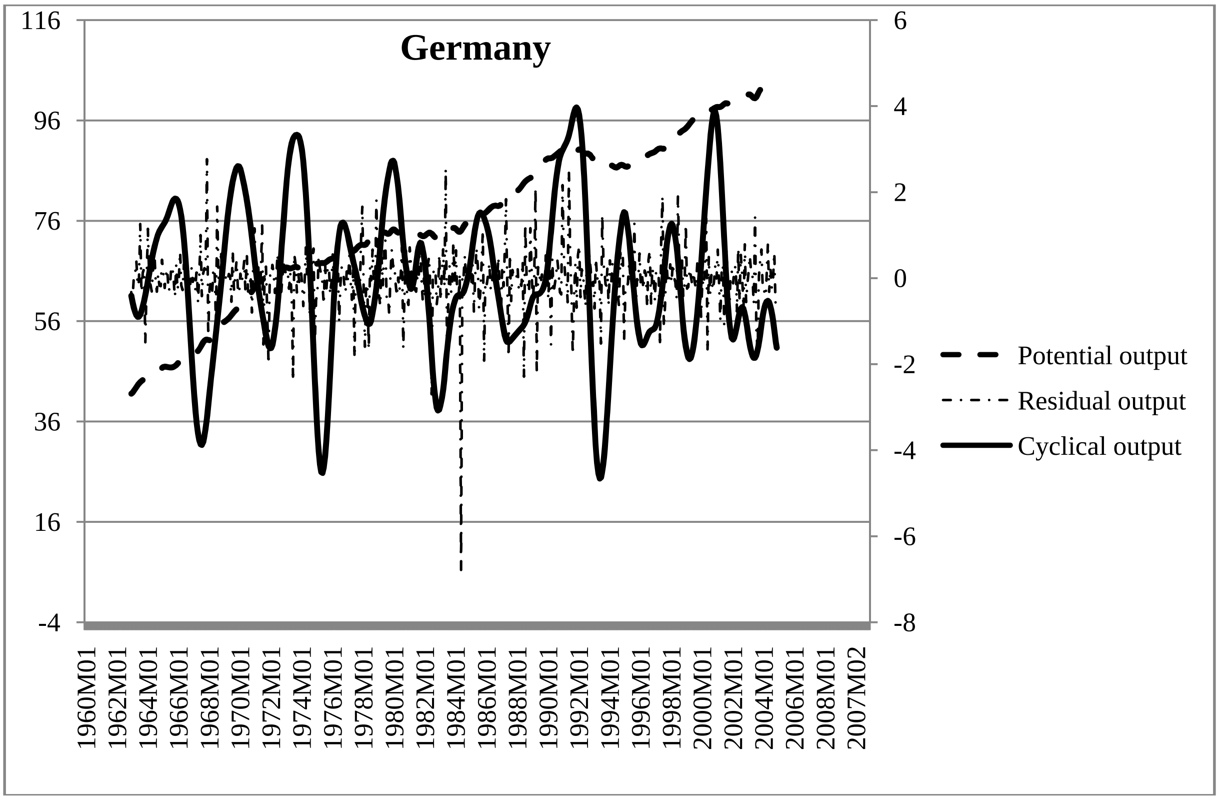
2003M02
2005M02
2007M02


Germany
116
96
76
56
36
16
-4
6
4
2
0
-2
-4
-6
-8
Potential output
Residual output
Cyclical output
1960M01
1962M01
1964M01
1966M01
1968M01
1970M01
1972M01
1974M01
1976M01
1978M01
1980M01
1982M01
1984M01
1986M01
1988M01
1990M01
1992M01
1994M01
1996M01
1998M01
2000M01
2002M01
2004M01
2006M01
2008M01
2007M02